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The calculation of evapotranspiration: a suggested modification to the MORECS scheme

by N Thompson

1. Introduction The present version of MORECS calculates evapotranspiration using the equation (Thom and Oliver 1977)

$$E_t = \frac{\Delta(R_n - G) + m\gamma E_{ap}}{\Delta + \gamma(1+n)} \quad (1)$$

where

E_t = evaporation in mm/day

Δ = $\partial e_{sat} / \partial T$

e = vapour pressure (mb)

$R_n - G$ = available energy (in mm equivalent of evaporated water)

n = a "constant" varying from month to month

γ = $0.66 \text{ mb deg C}^{-1}$

m = a constant determined by surface roughness

= $(7.3 / \ln(2/z_0))^2$ (At present MORECS uses a value for m of 2.5)

z_0 = surface roughness length

$E_{ap} = 0.26(1 + cU)(e_{sat} - e)$

U = wind speed at 2m height

$C = 0.54$ (for U in ms^{-1})

= 0.01 (for U in miles day $^{-1}$)

$e_{sat} - e$ = vapour pressure deficit

Equation 1 is a version of the "exact" equation for the flux density of latent heat from a vegetated surface (Monteith 1973)

$$\lambda E = \frac{\Delta (R_N - G)' + \rho c_p (e_s - e) / r_a}{\Delta + \gamma (1 + r_s / r_a)} \quad (\text{Wm}^{-2}) \quad (2)$$

where $(R_N - G)'$ is the available energy now expressed in Wm^{-2} . Here r_a is the aerodynamic resistance to transfer of heat and water vapour from the surface. Comparison of Eq. 1 and 2 shows that the value of n may be determined on a daily basis, provided E_{ap} has been calculated and r_s is known. At present MORECS assumes that n varies from month to month only with a typical value of order 1. From Eq 1 and 2 one may write (for U in ms^{-1})

$$0.26 m \gamma (e_s - e) (1 + 0.54 U) = A \rho c_p (e_s - e) / r_a \quad (3)$$

$$\text{or} \quad r_a = A \rho c_p / (0.26 m \gamma (1 + 0.54 U)) \quad \text{ms}^{-1} \quad (4)$$

A is a factor ($=0.035$) converting Wm^{-2} to the equivalent evaporation in mm per day. A typical value for m is about 2.5, corresponding to $z_0 = 0.02\text{m}$, for which

$$r_a \approx 100 / (1 + 0.54 U) \quad \text{ms}^{-1} \quad (5)$$

r_s is about 30 ms^{-1} for a dense, well-watered crop and so

$$n \approx 0.3 (1 + 0.54 U) \quad (6)$$

Thus n is equal to about 0.7 for a typical summer wind speed of 2.5 ms^{-1} .

2. A suggested modification to MORECS The assumption in MORECS is that a constant value for n may be used for any particular month, and will obviously lead to overestimates of evapotranspiration at exposed (e.g. coastal) sites in particular and at any place where the mean wind speed over the period of calculation exceeds the long-term areal monthly average. If, for example, the actual wind speed is 5 ms^{-1} instead of an assumed long-term average of 2.5 ms^{-1} the percentage over-estimation in E_t at a temperature of 20 deg C is

$$\left(\frac{1.45 + 0.66 (1 + 0.3 (1 + 0.54 \times 5))}{1.45 + 0.66 (1 + 0.7)} - 1 \right) \times 100$$

$$= 10.5\%$$

At lower temperatures the overestimate is larger: at 15 deg C the corresponding value is 12%. This error may contribute in part to the apparently excessive values of evapotranspiration often produced by MORECS when using data from coastal stations. Similar calculations for a roughness length of 0.1 m show overestimates of 19% and 21.5% after correcting m and n using the new value for z_0 .

The extra computational work involved in producing the more accurate estimates of evapotranspiration is small, and now that representative values of r_s are available for typical crops (e.g. Wales-Smith and Arnott 1979) it is recommended that the equation

$$E_t = \frac{\Delta(R_n - G) + 0.17m(1 + 0.54u)(e_s - e)}{\Delta + 0.66\left(1 + \frac{m\gamma}{250}(1 + 0.54u)\right)} \quad (7)$$

is used instead of the corresponding MORECS formulation.

Any comments or suggestions on this paper should be referred to the author.

Meteorological Office, Met O 8a
London Road
Bracknell, Berkshire

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References

- Thom, A S and Oliver, H R - 1977 - On Penman's equation for estimating regional evaporation, Quart J.R. Met Soc, 103, 345-357.
- Wales-Smith, B G and Arnott, J A - 1979 - The Meteorological Office Rainfall and Evaporation Calculation System (MORECS), Unpublished Manuscript.